CHAPTER 5

QUARRY SUPERVISOR

This chapter provides information on the selection and operations of pits and quarries. It describes basic principles of site selection, preparation, and methods and techniques of developing pits and quarries.

QUARRY SUPERVISOR RESPONSIBILITIES

Pit and quarry operations in the Naval Construction Force (NCF) are normally managed by Alfa company. The operations chief of Alfa company is usually responsible for the pit and quarry operations and normally assigns a quarry supervisor to direct the operations of the pit and quarry.

PITS AND QUARRIES

The operation of the pit and quarry is directly determined by the material requirements and tasking for construction projects and rock crushing operations. The size of the crew assigned to support the pit or quarry operations is dictated by the availability of the equipment and material required for a construction task.

Pits and quarries are classified according to the type of material they contain and the methods used to excavate and process the material (table 5-1).

Pits

Pits are excavations made at the earth's surface in unconsolidated materials, such as clay, sand, gravel, coral, and laterite. They are sites from which suitable construction materials are obtained in quantity, being removed or extracted from the surface without the use of blasting. Alluvial or stream-deposited gravel pits yield gravel that is usually clean and free of clay and humus and are therefore desirable for concrete and bituminous work. Bank or hill gravel pits yield a clayey gravel that is desirable for road or runway surfacing because of its binding qualities. Gravel is also used for base courses and fills. Soil (other than sand and gravel) selected for use in embankments, fills, and subgrades is obtained from borrow pits. Miscellaneous pits contain mixed tailings, slag, cinders, or the like, which are also used for road or runway surfacing and as aggregates.

Quarries

Quarries are sites where large, open excavations are made for the purpose of extracting or removing rock in its natural state by drilling, cutting, and blasting. In some cases, it may be possible to remove and break up rock by use of dozer rippers and bull pricks (jack hammer attachment). The primary types of rocks obtained from quarries are igneous and metamorphic, such as trap rock, granite, diorite, geneiss, quartize, and certain shales. Military quarries are generally open-faced, which means the vertical surface of the rock is exposed. Since seldom used in its inplace state, quarry rock is processed with mobile equipment that crushes, screens, and washes.

SITE SELECTION

Before a pit or quarry is located, an investigation of the site must be performed to establish that suitable construction materials are available in adequate amounts and that the excavation can be worked efficiently with available equipment. Whenever possible, existing pits and quarries are used because (1) the quantity and quality of materials can easily be determined; (2) good haul and access roads are probably already built; (3) less effort can be spent on removal of overburden; and (4) facilities, such as ramps, hoppers, bins, power, and water, are generally available.

The chosen site should be as close as possible to the construction project and convenient to good routes of transportation. This allows more efficient hauling by decreasing the length of haul roads. Pit and quarry haulage is usually accomplished with equipment, such as dump trucks and scrapers.

Soil Formation

The formation of soil is a continuous process. Basically, the crust of the earth consists of rock that geologists classify into three groups: igneous, which is formed by cooling from a molten state; sedimentary, formed by the accumulation and cementing of existing particles and remains of plants and animals; and metamorphic, formed from existing rocks that have been subjected to heat and pressure. When the rock is

Table 5-1.-Classification of Pits and Quarries

Type	Material	Primary Use	Operating Equipment
PIT:			
Borrow:	Select soil other than sand and gravel.	Fill for embankments and subgrades.	Scraper, dozer, rooter, power shovel, front loader, or dragline and dump trucks.
Sand or gravel: (Bank or Hill)	Sand and gravel with clay.	Base course, subbases, and fills.	Scrapers or power shovel, front loader, or hand tools and dump trucks.
(Alluvial)	Clean sand and gravel.	Aggregates for concrete and bituminous mixes and free-draining, nonfrost susceptible fills.	Power shovel, front loader, dragline, or clamshell and dump trucks.
Miscellaneous: (Dumps)	Slag, mine tailings, cinders, etc.	Surfacing, tills, and aggregates.	Power shovel, front loader, or hand tools and dump trucks.
QUARRY:			
Hard rock	Hard, tough rocks like granite, felsite, gabbro, diorite, basalt, quartzite, and some sandstones, limestones, and dolomites.	Aggregates for base courses, surfacing, concrete and bituminous mixes, free-draining tills and stone for riprap, embankments, and marine structures.	Rock drill, blasting materials and machine, power shovel, front loader, dump trucks, and crushing, screening (and washing) plant.
Medium rock:	Moderately hard, tough rocks like most sandstones, limestones, solomites, and marbles.	Base courses and surfacing on roads and airfields and aggregates for some concrete and bituminous mixes.	Rock drill, blasting materials and machine, power shovel, front loader, dump trucks, and crushing, screening (and washing) plant.
Soft rock:	Cementaceous materials like limerock, coral, caliche, tuff, and laterite or weak rocks like disintegrated granite and some sandstones or conglomerates.	Fills and base courses and surfacing for roads and airfields.	Rooter, power shovel, front loader, and earth moving equipment.

exposed to the atmosphere, it undergoes a physical and chemical process called WEATHERING, which, over a sufficient length of time, disintegrates and decomposes the rock into a loose, incoherent mixture of gravel, sand, and finer material.

Soil Quality

The intended use of the soil is the determining factor in the quality required. In general, soil used for fills and subgrades do not have to meet the same specifications as those used for compacted rock surfaces, base courses, or pavements.

Seven properties of rock are used to help select rock and aggregates for construction. Briefly, these rock properties are as follows: toughness, hardness, durability, chemical stability, crushed shape, surface character, and density. Toughness, hardness, and durability are commonly checked in the field with a simple field test.

Hardness is the resistance of a rock to scratching or abrasion. This property is important in determining the suitability of aggregate for construction. Hardness can be measured using the Mob's scale of hardness (table 5-2). The harder the material, the higher its number on the Moh's scale. Any material will scratch another of equal or lesser hardness. In the field, hardness may be measured using the common expedients shown in table 5-2; for example, when you are able to scratch a rock with a knife blade, the rock has a hardness of 5.0 or less. A rock which can be scratched by a copper coin has a hardness of 3.0 or less.

Table 5-2.-MOH'S Scale of Hardness

Mineral	Hardness
Diamond	10
Corundum	9
Topaz or beryl	8
Quartz	7
Feldspar	6
Apatite	5
Fluorite	4
Calcite	3
Gypsum	2
Talc	1
Expedients	
Porcelain	7.0
Steel file	6.5
Windowglass	5.5
Knife blade	5.0
Copper coin	3.0
Fingernail	2.0

Aggregates for general construction should have a hardness of 5 to 7 and should be difficult or impossible to scratch with a knife. Material with a hardness greater than 7 should be avoided since they cause excessive wear to crushers, screens, and drilling equipment. Material with a hardness of less than 5 may be used if other sources of aggregate prove uneconomical.

The requirements as to toughness, durability, crushed shape, and other properties vary according to the type of construction. Chemical stability has specific importance when considering aggregates for concrete. Several rock types contain impure forms of silica that reacts with alkalies in cement. This reaction forms a gel that absorbs water and expands to crack or disintegrate hardened concrete. These reactive materials may be included in some gravel deposits as pebbles or as coatings on gravel. Potential alkali-aggregate reactions may be anticipated in the field by identifying the rock and comparing it to known reactive types or by investigating structures in which the aggregate has been used. Generally, light-colored or glassy volcanic rocks, chert, flints, and clayey rocks should be considered reactive unless proven otherwise.

An additional property of rock is gradation (fig. 5-1). This property is also important for evaluating rock as possible construction material. Gradation is the distribution and range of particle sizes that are present in, or can be obtained from, a deposit. The gradation of pit materials can be readily determined from a simple test. Quarry materials may be more difficult to evaluate.

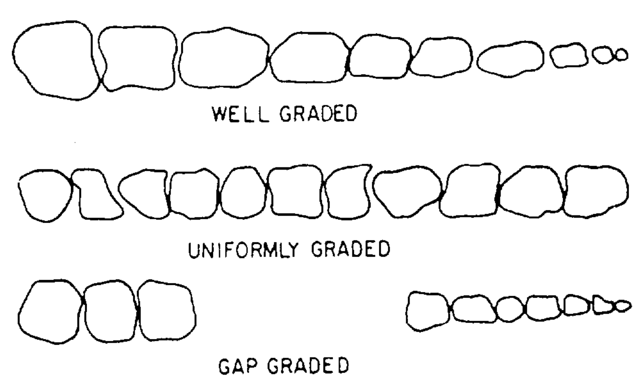

Figure 5-1.-Types of soil gradation.

MAJOR DIVISIONS 1	2	LETTER 3	SYMBOL HATCHING 4	SYMBOL COLOR 5	NAME 6
COARSE-GRAINED SOILS	GRAVELS AND GRAVELLY SOILS	GW		RED	GRAVEL OR SANDY GRAVEL WELL GRADED
		GP			GRAVEL OR SANDY GRAVEL POORLY GRADED
		GM		YELLOW	SILTY GRAVEL OR SILTY SANDY GRAVEL
		GC			CLAYEY GRAVEL OR CLAYEY SANDY GRAVEL
	SANDS AND SANDY SOILS	SW		RED	SAND OR GRAVELLY SAND WELL GRADED
		SP			SAND OR GRAVELLY SAND POORLY GRADED
		SM		YELLOW	SILTY SAND OR SILTY GRAVELLY SAND
		SC			CLAYEY SAND OR CLAYEY GRAVELLY SAND
FINE-GRAINED SOILS	SILT AND CLAY SOILS (LOW LIQUID LIMIT)	ML		GREEN	SILTS, SANDY SILTS, GRAVELLY SILTS, OR DIATOMACEOUS SOILS
		CL			LEAN CLAYS, SANDY CLAYS, OR GRAVELLY CLAYS
		OL			ORGANIC SILTS OR LEAN ORGANIC CLAYS
	SILT AND CLAY SOILS (HIGH LIQUID LIMIT)	MH		BLUE	MICACEOUS SILTS, DIATOMACEOUS SOILS, OR ELASTIC SILTS
		CH			FAT CLAYS
		OH			FAT ORGANIC CLAYS
FIBROUS ORGANIC SOILS		Pt		ORANGE	PEAT, HUMUS, AND OTHER ORGANIC SWAMP SOILS

Figure 5-2.-Conventional graphic soil symbols.

Normally, the upper limit of particle sizes available is controlled by the thickness of rock layers and the spacing of cracks or fractures in the rock. The amount of fine particles produced during rock crushing operations can be highly variable. Generally, hard, tough rocks produce few fines, and soft, weak rocks produce large quantities of fines. Weak sandstones and granites usually produce large amounts of sand-size materials.

Types of Quarry Material

Natural sand and gravel are not always available, and it is sometimes necessary to produce aggregate by quarrying and processing rock. Quarrying normally is performed only where other materials of adequate quality and size cannot be obtained economically.

Many rock types suitable for construction exist throughout the world; therefore, the quality and durability of the rock type selected depends on local conditions. The following rock types are generally easy to quarry, durable, and resistant to weathering, When these are not available, it may be necessary to use softer rocks for base courses and surfacing on a temporary basis. The softer rocks will usually require little or no blasting.

Granite. As a dimension stone, granite is fairly durable and has a texture and color desirable for polishing. As a construction material for base courses and aggregate, it is not as desirable as some of the more dense, fine-grained igneous rock.

Felsite–Rhyolite. This is durable and makes a good aggregate for base courses. It is not suitable for concrete aggregate.

Gabbro-Diorite. Gabbro and diorite both have good strength and durability. The mineral crystals of both rocks are deeply intermeshed, making them very tough and excellent for construction aggregate.

Basalt. The dense variety of basalt, when crushed, is excellent for use as a base course. It is very strong and durable.

Sandstone. Few sedimentary rocks are desirable for construction due to their variable physical properties; however, sandstone is generally durable. Because of the variable nature of the types of grains and cement, each deposit must be evaluated individually.

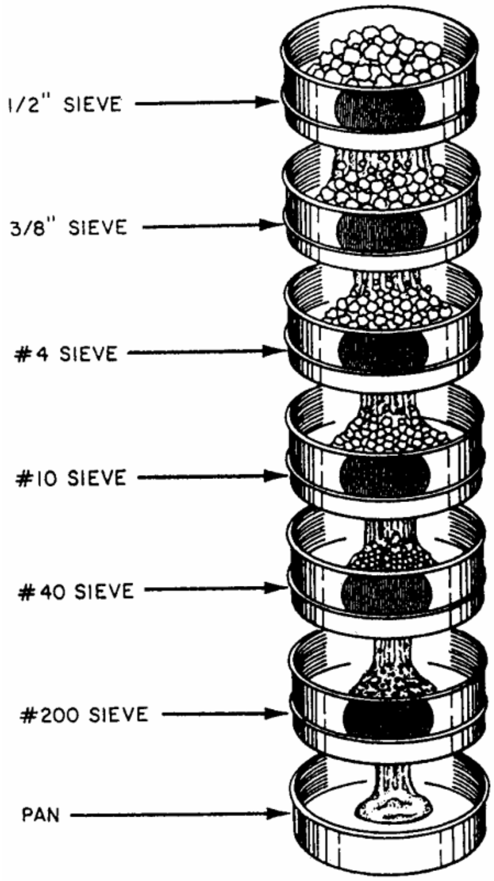

Figure 5-3.-Sieve sizes.

Limestone. Limestone is widely used for road surfacing, in concrete, and for lime.

Gneiss. Most varieties of gneiss have good strength and durability and make good road aggregates.

Quartzite. Quartzite is both hard and durable. Because of these qualities, it is an excellent rock for construction, although it is often difficult to quarry.

Marble. The texture and color of marble make it very desirable for dimension stone, and it can be used for base course or aggregate material.

Sieve Analysis

Soil is composed of particles of various sizes and composition. Figure 5-2 shows the major types of soils. Soil can be analyzed by size by sifting a dried and weighed sample through a set of testing sieves (fig. 5-3) and weighing the material retained on each screen. Further testing may be required by the specifications for the product you need to produce. These tests are normally performed by the soil laboratory in the engineering department of the battalion.

Soil is classified according to the particle size, such as coarse aggregate, fine aggregate, and mineral filler. The maximum size of the aggregate varies, depending upon the construction specifications. Particle size is defined by passing a soil mass through several sieves with different sized openings (fig. 5-3).

Particles that pass through a given sieve are said to be passing that sieve size. Particles that fail to pass through a given sieve are said to be *retained on* that sieve. The sieve permits particles smaller than the opening to fall through and retains the larger particles on the sieve. When you use sieves with screen openings of different sizes, the soil can be separated into particle groups based on size.

A weighted sample of aggregate is placed in the top sieve, and the entire set of sieves (largest on the top, smallest on the bottom) is vibrated either by hand or mechanically. The individual weights are calculated as a percentage of the total weight, as shown in the following example: Assume we take 3,000 grams of soil mass and determine how much aggregate passes each sieve.

Aggregate passing 1/2-inch sieve and retained on 3/8-inch sieve = 720 grams = 24%

Aggregate passing 3/8-inch sieve and retained on No. 4 sieve = 600 grams = 20%

Aggregate passing No. 4 sieve and retained on No. 10 sieve = 450 grams = 15%

Aggregate passing No. 10 sieve and retained on No. 40 sieve = 570 grams = 19%

Aggregate passing No. 40 sieve and retained on No. 200 sieve = 420 grams = 14%

Aggregate passing No. 200 sieve = 240 grams = 8%

3,000 grams = 100%

The above percentages are one way of expressing the gradation of a sample of aggregate.

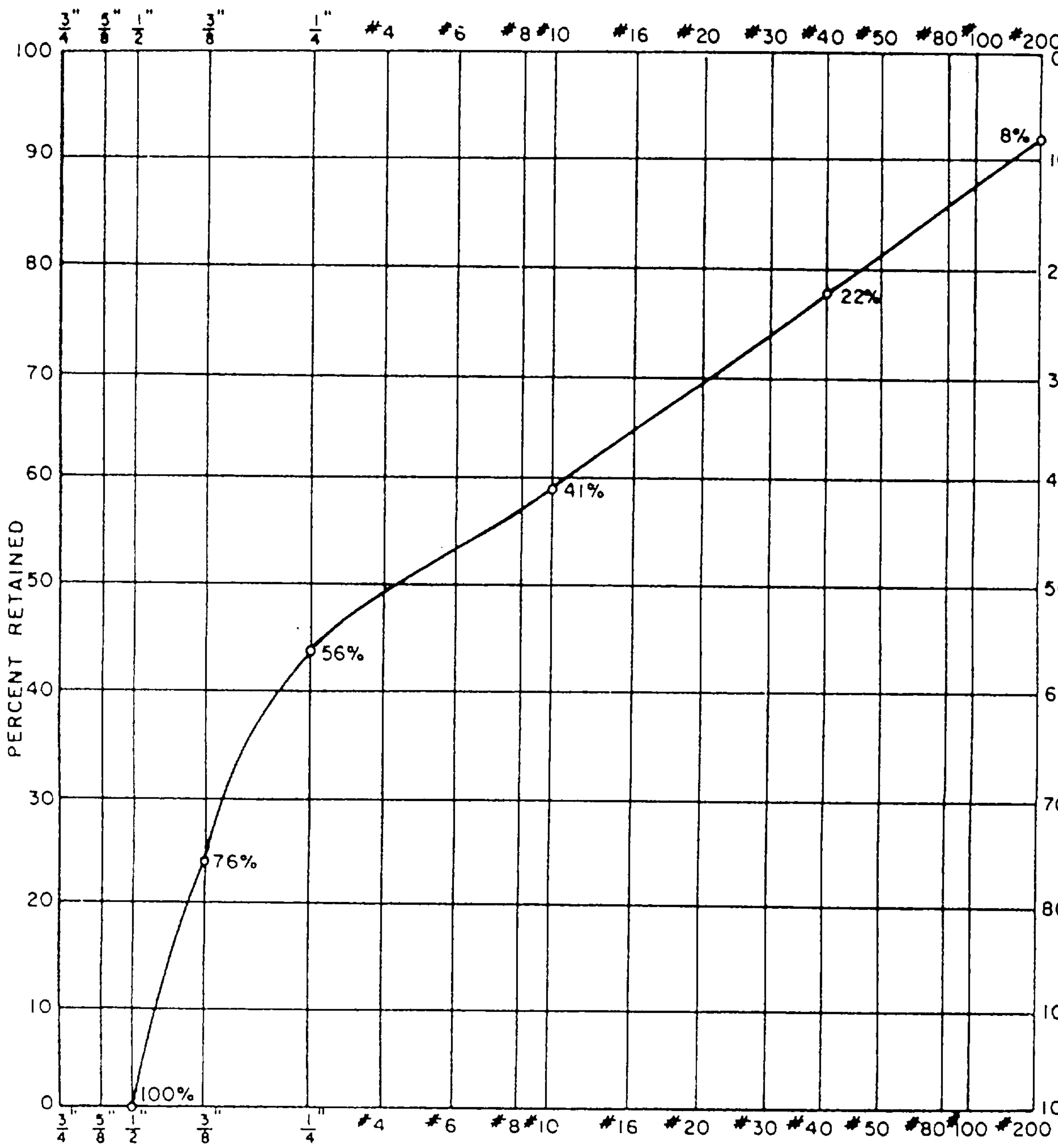

Figure 5-4.-Sieve analysis.

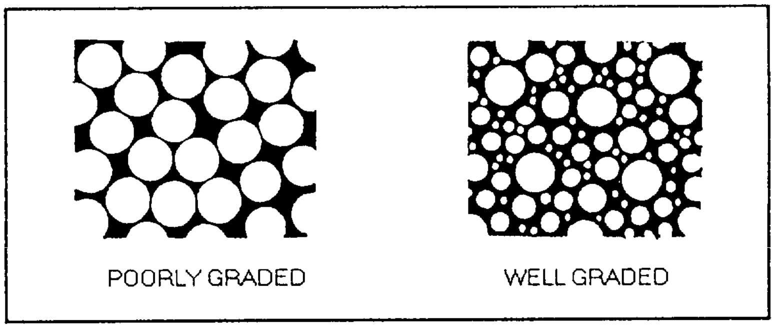

Figure 5-5.—Compactive soil.

Another method, more commonly used, is to express the gradation in terms of the **TOTAL PERCENTAGE** that passes each sieve. This is determined by adding the listed percentage that passed each sieve and was retained on the next finer sieve to the percentages listed beside each of the sieves below it.

For example, in the sample just analyzed, 24% passed the 1/2-inch sieve and was retained on the 3/8-inch sieve. The total percentage that passed the 1/2-inch sieve is 24% + 20% + 15% + 19% + 14% + 8% = 100%

The total percentage that passed the 3/8-inch sieve is 20% + 15% + 19% + 14% + 8% = 76%. Continuing the calculation as indicated, the results of the test in terms of total percentage passing each sieve are as follows:

Aggregate passing 1/2-inch sieve	= 3,000 grams = 100%
Aggregate prosing 3/8-inch sieve	= 2,280 grams = 76%
Aggregate passing No. 4 sieve	= 1,680 grams = 56%
Aggregate passing No. 10 sieve	= 1,230 grams = 41%
Aggregate passing No. 40 sieve	= 660 grams = 22%
Aggregate passing No. 200 sieve	= 240 grams = 8%

Figure 5-4 shows the aggregate gradation curve for this particular example, plotted by using the above percentages.

For bituminous aggregate, anything that passes the No. 4 sieve and is retained on the No. 200 sieve is considered *FINE* aggregate. Anything retained on the No. 4 sieve is considered *COARSE* aggregate.

Material that can pass a No. 200 sieve is sometimes used in bituminous paving; this material is known as *MINERAL FILLER, DUST, OR FINES*. It consists of finely powdered rock, portland cement, hydrated lime, or some other artificially or naturally powdered dust.

All testing sieves larger than three-sixteenths of an inch are identified by the actual clear opening in inches. All testing sieves smaller than three-sixteenth of an inch are identified by mesh number. (See fig. 5-4.)

Compaction Qualities of Soil

Compaction is the process of physically densifying or packing the soil. The strength of any given soil can be increased by the densification obtained from compaction.

Three factors affect compaction: material gradation, moisture content, and compactive effort.

Material gradation (fig. 5-1) refers to the distribution of different sizes of particles within a given soil sample. A well-graded sample contains a good, even distribution of particle sizes. When the composition of a soil sample is made up mostly of one size of particles, this soil would be poorly graded. A well-graded soil will compact more easily than one that is poorly graded. In well-graded material, the smaller particles tend to fill the empty spaces (voids) between the larger particles, leaving fewer voids after compaction (fig. 5-5).

Moisture content is the amount of water present in the soil. Because water acts as a lubricant that helps particles slide into a denser position, the moisture content of a soil is very important to compaction. Water also helps bond clay particles, giving cohesive materials their sticky qualities.

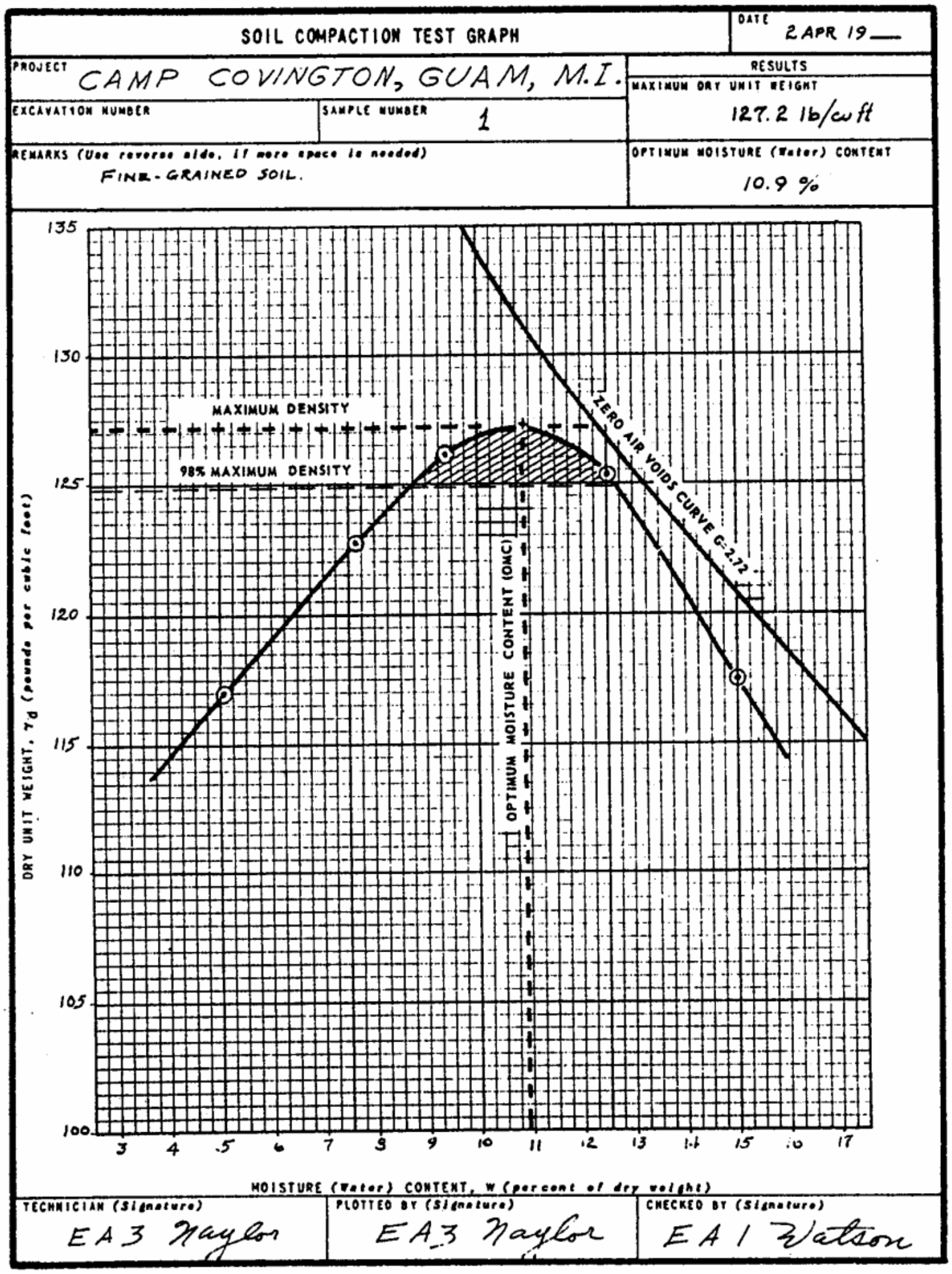

Figure 5-6.—Soil compaction test graph.

Experience has shown it is next to impossible to achieve proper compaction in materials that are too dry or too wet. Soil experts have proved that in every soil there is an amount of water, called the OPTIMUM MOISTURE CONTENT, at which it is possible to obtain maximum density with a given amount of compaction. Figure 5-6 is an example of a compaction curve that is used to show the relationship between dry density and moisture content. The soil laboratory performs and determines the optimum moisture content.

Compactive effort is the method by which the compactor imparts energy into the soil to achieve compaction. Compactors are designed to use one or a combination of the following types of compactive effort: static weight (pressure), kneading action, impact, or vibration.

PIT OR QUARRY SITE PREPARATION

Preparation of a new site should start immediately after the site location has been selected. Preparatory work includes making an operations plan, clearing the site, removing overburden, draining the site, building roads, loading ramps, and installing processing equipment.

Operations Plan

The operations plan is prepared before any earth is moved. The plan includes the limits of the site to be developed, methods of excavation, equipment to be used, number of personnel required, and locations of roads, structures, and support equipment. Also, plans for traffic control and drainage are established.

Clearing the Site

When the site is located in a wooded area, the first operation is to clear all timber, standing or fallen. If camouflage is necessary, trees or brush outside the designated cleared area should not be removed.

Construction equipment operations are usually the most rapid and efficient means of clearing a site. Use of the equipment is limited only by unusually large trees and stumps–terrain which hinders their maneuverability and maintenance requirements. The construction equipment used include bulldozers, winches, power saws, rippers, motor graders, and scrapers. In addition, hand tools are used in certain clearing operations.

Brush may be disposed of by burning on the site; however, check to see if a burn permit is required. Timber of suitable dimensions should be stockpiled at the perimeter of the site. This timber should be saved for possible use in construction of loading ramps. All stumps, roots, boulders, vegetation, and rubbish must be excavated and moved clear of the site.

Overburden

Overburden is usually removed from a pit or quarry site by a continuous process of stripping. The methods and equipment used in removing overburden are dependent upon the type of excavation planned, the depth of overburden, and the distance the overburden must be moved. It may be advantageous to leave inplace the overburden at military quarry sites and blast it with the rock to provide binder for road building materials. Removal is coordinated with excavation to provide a continuously cleared area. The spoil should be dumped in a remote area to avoid double handling. On hillside locations, the spoil should be placed in banks, located on the downhill side, outside the working area.

Remember that all overburden is not necessarily waste. Some of the overburden is suitable for filling, building access roads, and leveling stockpile and equipment sites.

In excavating aggregates for concrete, bituminous mixtures, or base courses, the overburden must be removed while the aggregates are processed. Frozen material is loosened either with a ripper or explosives. Overburden should be kept cleared at least 50 feet back from the top of the face of a quarry or pit to prevent rock and other material from falling on personnel working near the top of the face. Also, overburden should be cleared far enough back from the top so the equipment being used to clear the overburden does not interfere with drilling operations.

Drainage

Adequate drainage is essential to the operation of a pit or quarry. Alluvial gravel pits may be worked wet or dry, depending on water levels. Borrow pits and quarries are normally worked dry.

Drainage facilities are installed as early as possible so the site will be dry when work starts. The means of drainage depends primarily upon the location and the amount of water to be eliminated. Hillside locations are easy to drain by an interceptor ditch made along the uphill side with a scraper, dozer, or grader. When the floor of a site is belowground level, both surface and seepage water must be disposed of. When open ditches cannot be dug to take advantage of gravity flow, all water is directed to a sump hole. A slight slope on the site floor must be maintained at all times to permit water to drain away from the working face of the site.

Roads

Construction of access roads should start as soon as the operations plan is completed so they are ready for use when the pit and quarry equipment arrives. The access roads should be designed for all-weather operation under the heaviest loads anticipated. The roads should follow the shortest and easiest routes that satisfy the traffic control plan. To speed up hauling, you must avoid sharp curves and grades kept as low as possible. Ten percent grade (10-foot drop or climb every 100 feet) is the maximum grade for truck operations, whereas tractors and graders can climb 20-percent grades for short distances.

Except for the loop at the loading site, access roads should provide one-way traffic—one route to enter and another to haul out. Leave enough space between haul roads and borrow pits to avoid traffic hazards.

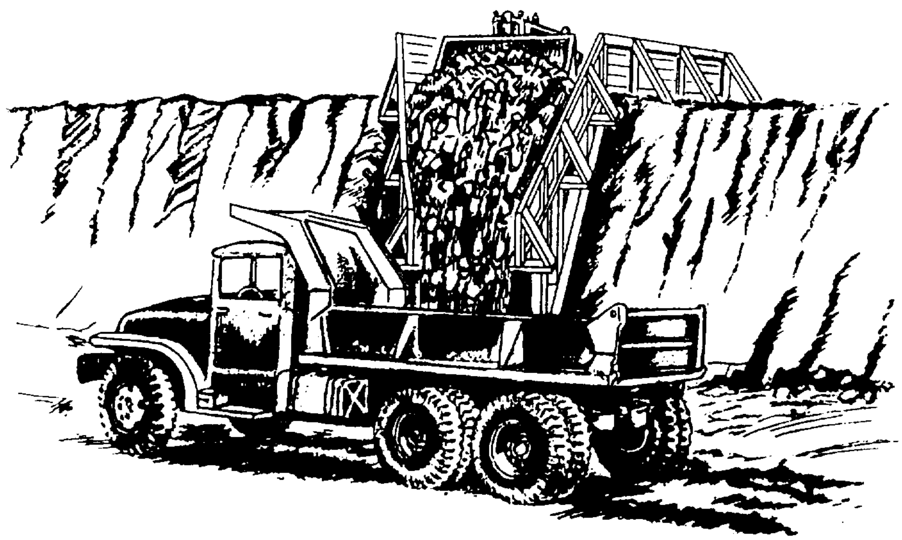

Figure 5-7.-Plain chute loading ramp.

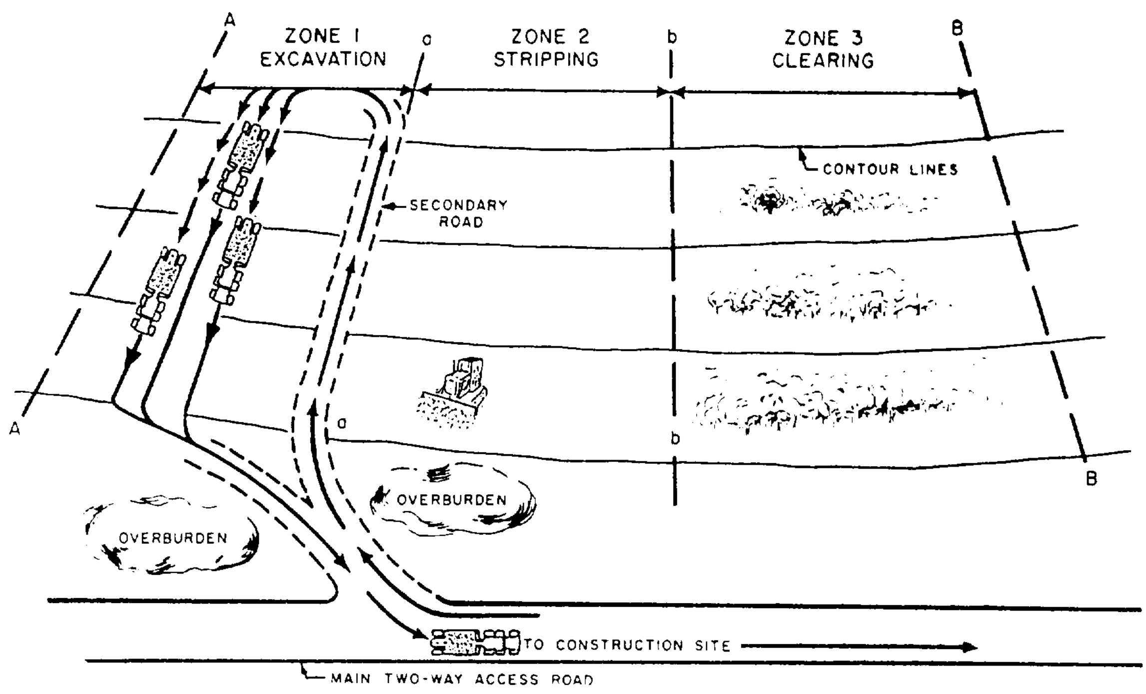

Figure 5-8.-Layout and development of a scraper pit.

Chute Loading Ramps

A chute loading ramp is an expedient means of loading excavated material into trucks with earth moving equipment at sites where loaders and clamshells are unavailable. An elementary type of loading ramp is the plain chute (fig. 5-7). Each ramp must be able to support the heaviest equipment used, plus an impact factor of 50 percent, and approximately 20 ton; of material.

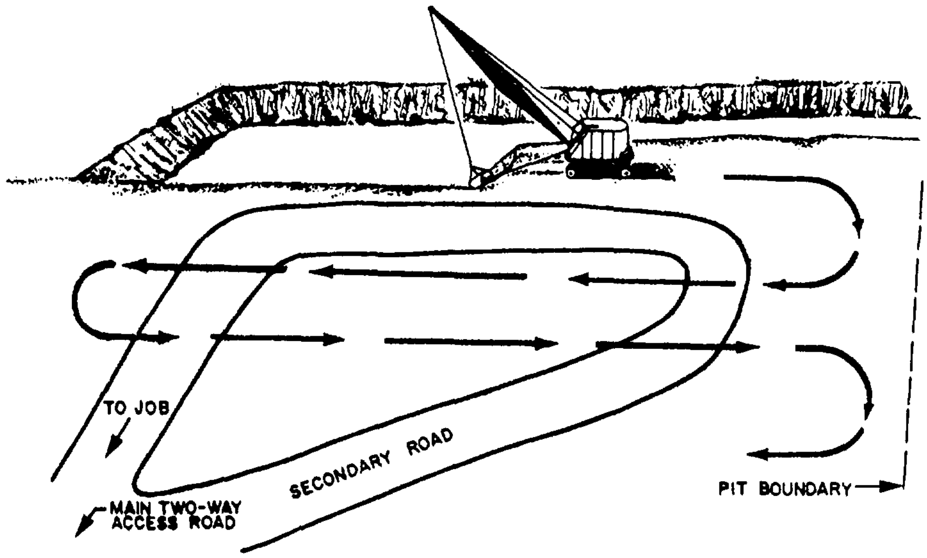

Figure 5-9.-Layout and development of a pit, using a dragline.

PIT OPERATIONS

Sand, gravel, and other construction materials are extracted from pits with scrapers that can move huge volumes of material in a relatively short period of time. The material is removed from the floor of the pit in successive thin layers over its entire width.

During excavation, scrapers should be carefully spotted to maintain an even downgrade and prevent cutting holes below the general level of the pit floor. When the pit is longer than 100 feet in the direction of loading, the scraper spots should be staggered along the length of the cut as well as across the width of the zone. Figure 5-8 depicts the layout and development of a scraper pit with lines A-A and B-B showing the limits of the pit. Lines A-A and B-B divide the area into three zones for current excavating, stripping, and clearing. Zone 1 is being excavated at the same time Zone 2 is being stripped and Zone 3 is being cleared. Three scrapers in staggered formation load downhill in Zone 1, and a dozer strips downhill in Zone 2.

In consolidated gravel or soft rock, when scrapers assisted by pusher tractors (Push Cat) will not pickup a heaping load within 150 feet, a ripper should be used to loosen the material, thereby increasing the loading efficiency of the scrapers. Rippers should be operated downhill, and an entire zone should be ripped at one time while the scrapers are hauling from another zone.

The dragline is the most practical piece of construction equipment for underwater digging and is particularly adapted to submerged gravel pit operations. Draglines can efficiently recover sand, gravel, laterite, or coral from beaches, the beds of streams, and the bottoms of lakes and lagoons. Figure 5-9 depicts the layout and development of a pit being excavated with a dragline.

Clamshells are capable of excavating loose sand, gravel, and crushed stone at, above, or below ground level. The clamshell can be raised and loads dumped at heights equal to the distance from the tip of the boom to the ground, minus the length of the clamshell bucket, to allow adequate clearance for the bucket when it is opening.

Material removed from pits can seldom be used in its inplace state. In most cases, pit material must be processed (crushed and screened) to meet job specifications. But, before the material can be processed, it must be loaded and delivered to the processing equipment. Loading and delivery may require additional handling equipment, such as front-end loaders equiped with either a rollback bucket or 4-in-1 bucket and conveyers that may be used singly or in series to load vehicles, construction equipment, or hoppers from stockpiled material. Bucket loaders may also be used. They consist of a power-driven endless chain to which buckets are attached so material is loaded on the downward travel. Handling equipment is used to

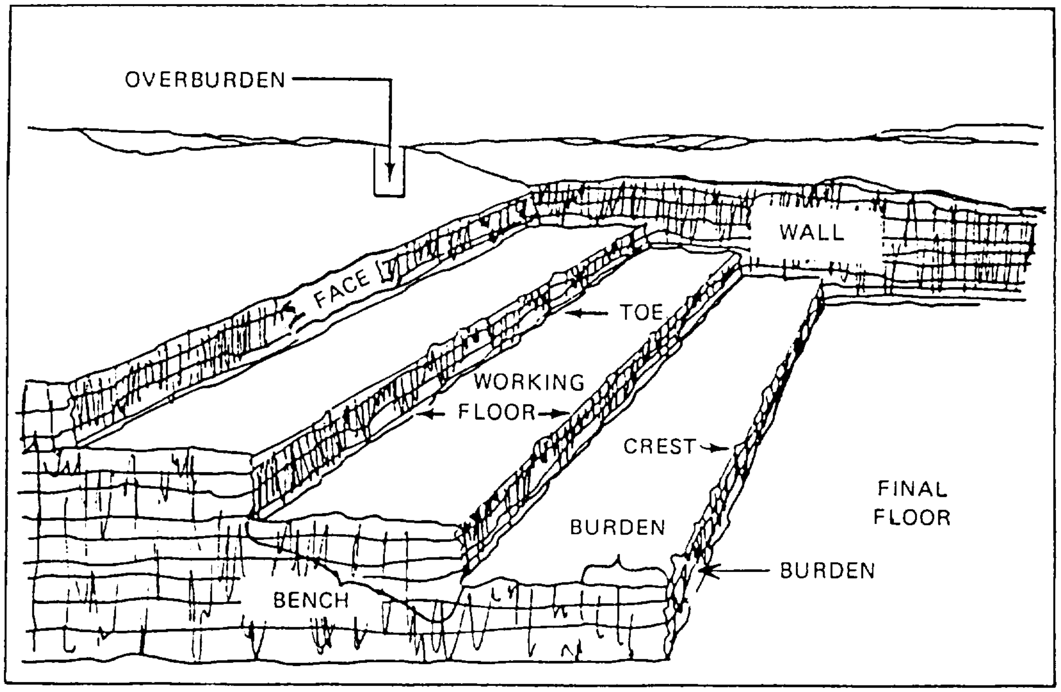

Figure 5-10.–Quarry terminology.

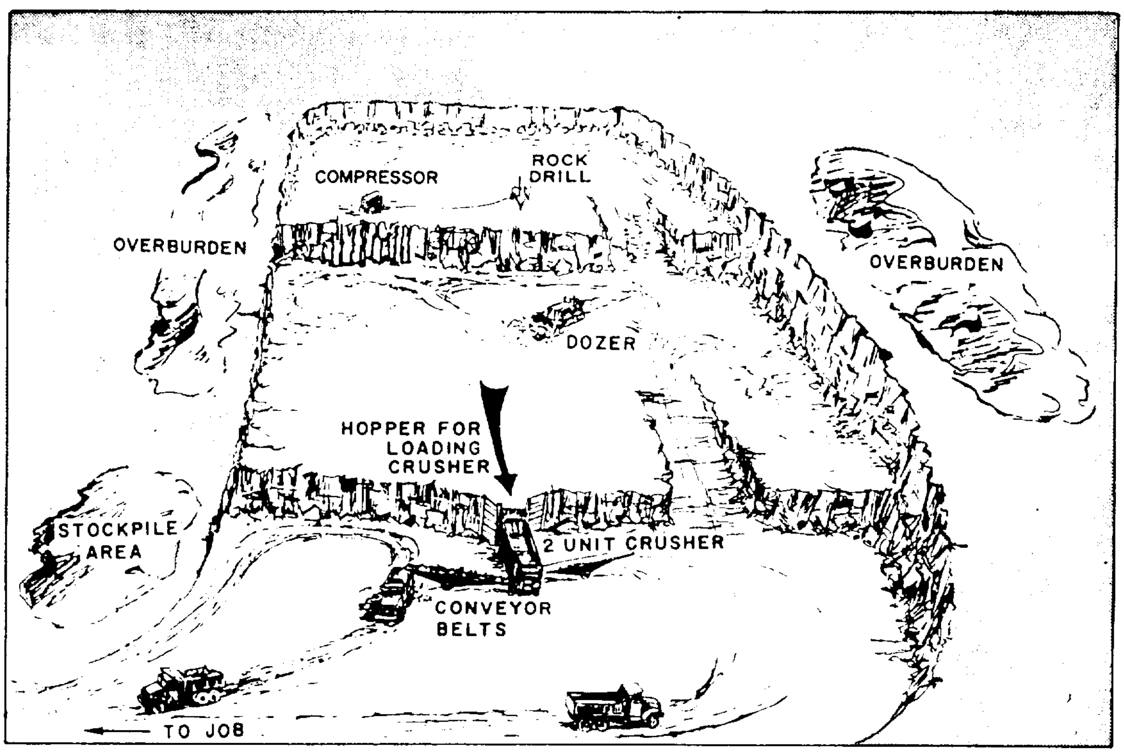

Figure 5-11.–Typical quarry layout.

load stockpiled material into overhead hoppers and trucks.

The production of any pit material that requires crushing and screening depends on the capacity of the processing equipment used.

QUARRY OPERATIONS

Quarrying involves not only extraction of material (rock) but also crushing and screening that makes the rock suitable for use as construction material.

Quarry Terminology

Figure 5-10 shows the names of various quarry features. *Overburden* is the waste material that often overlies pit or quarry sites. Deposits within the waste materials are called spoil and must be removed before excavation of the construction materials lying below. Overburden refers to loose material but locally it may include solid rock lying above the desired material. *Burden* is the construction material on the face of a quarry. The *floor* of the quarry is the inside bottom surface that marks the lower limit of excavation. Often quarries contain one or more *working floors* at various levels above the final quarry floor. A quarry *wall* is a more or less vertical surface that marks the lateral limit of excavation. The *face* of a quarry is a rock surface (usually vertical) from which rock is to be excavated. The top of the face is called the *crest,* and the bottom is called the *toe.* A *bench* is a steplike mass of rock behind a face and below a working floor, Notice that each bench has a face, toe, and crest.

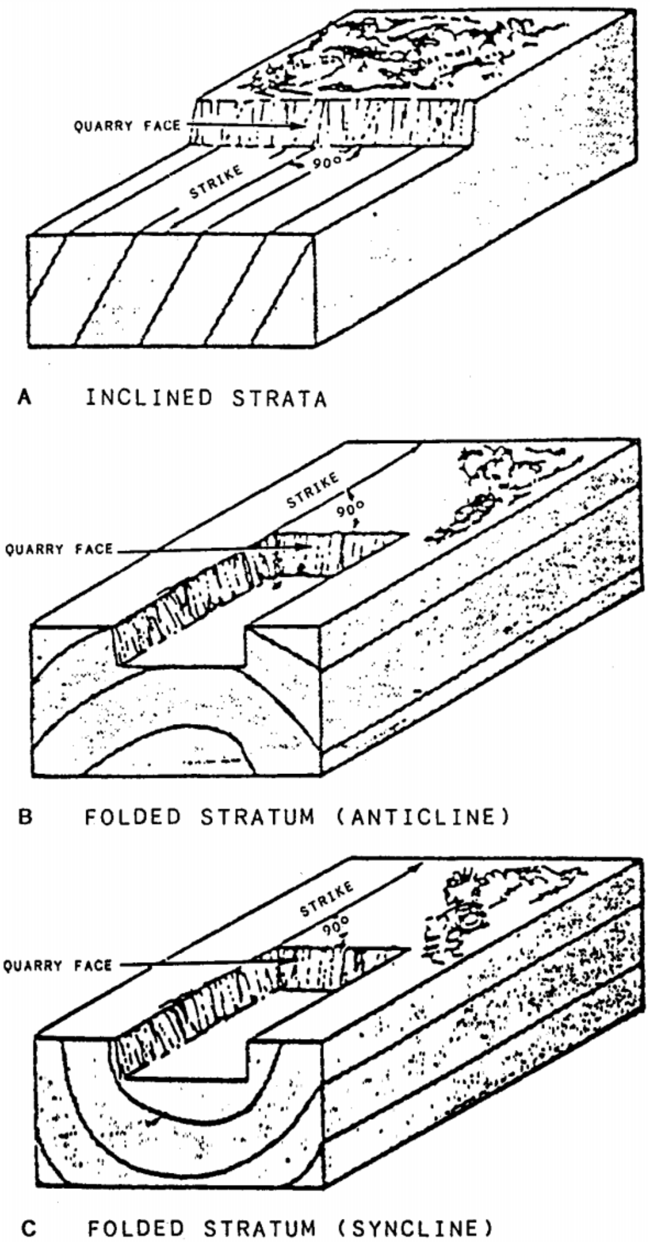

Figure 5-12.-Determining the direction of the quarry face.

Quarry Development

The layout of a quarry should provide a gravity flow of material from the face to the crusher, from the crusher to the storage bin, and from the bin to the hauling equipment, as illustrated in figure 5-11. A quarry laid out in this manner assures that a maximum quantity of rock can be processed with a minimum of labor and equipment. In quarries laid out on the gravity-flow principle, the drainage problem is practically eliminated.

Military quarries are generally of the open-face type with the vertical surface of the rock exposed. Depending upon local conditions, they may be developed by the single- or multiple-bench method.

Where the rock face is not exposed, core samples should be taken in a grid pattern so rock formations can be plotted, and the lay of the strata, the quality and quantity of the deposit, and depth of overburden can be determined. Should a rock formation be jointed or stratified, the layout of the quarry is determined by the strike (direction) of the formation; that is, the face of the quarry must be directed at right angles to the strike (fig. 5-12). This ensures a vertical or near vertical face with less chance of undercutting the face and creating a dangerous overhang.

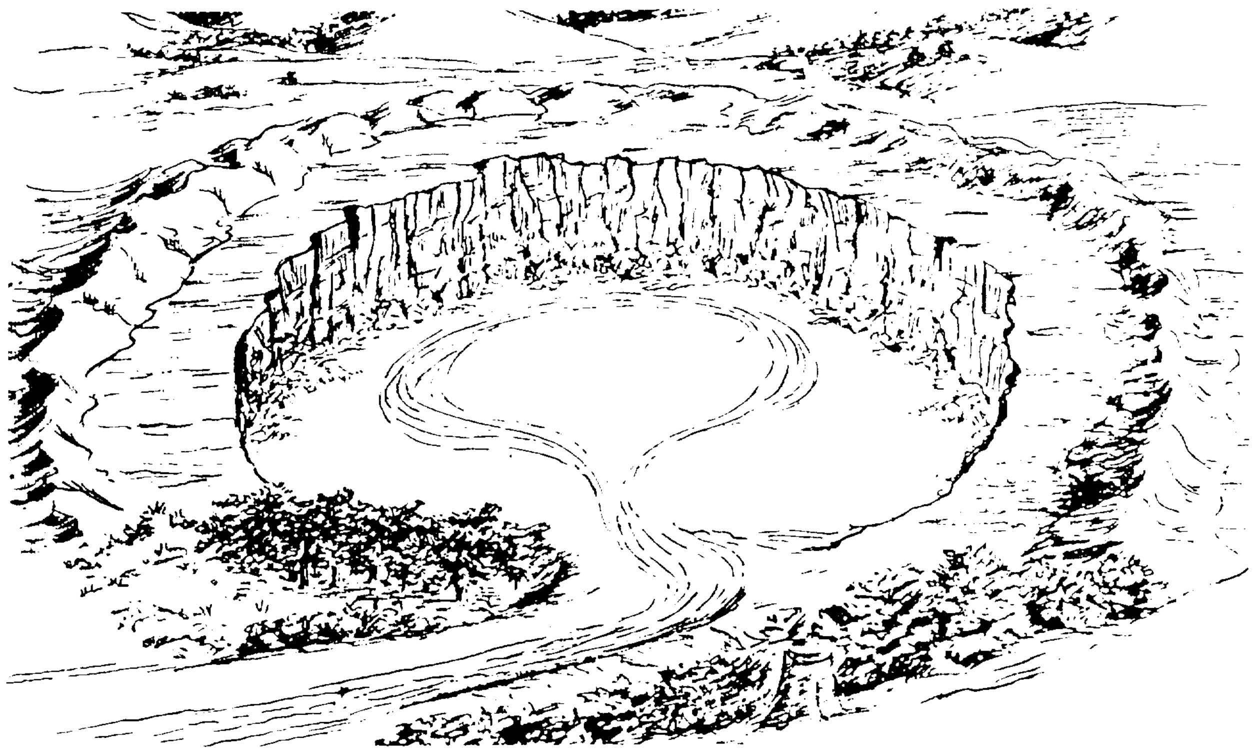

Figure 5-13.-Single-bench quarry.

A single-bench quarry (fig. 5-13) is one having the entire floor on one level. The height of the bench will depend on the reach of the equipment available. In the NCF, the recommended bench height is 10 feet; however, depending on the drilling equipment available, type of rock, magnitude of operation, and experience of the operating personnel, bench heights can range from 8 to 40 feet.

Military quarries are usually of the single-bench type. This type offers greater safety and efficient operation. All operations are on one level, a greater amount of rock is shot at one blast, and less equipment is needed in the overall process. In addition, this type of quarry requires less training for the operating crews.

Blast trial shots are made in both existing and new quarries before installing equipment for two reasons. First, to avoid possible damage to installed equipment and the second, in the case of new quarries, is that the trial shots will provide necessary ballast to construct access roads and for foundations to place equipment upon.

WARNING

Blasting must be supervised and controlled directly by a qualified blaster. Also, all personnel working around blasting should wear hard hats, safety goggles, dust respirators, earplugs, and hard toe safety shoes.

A multiple-bench quarry (fig. 5-14) is one having a series of ledges or terraces resembling steps. The highest bench is blasted and worked first. Then successive lower levels are simultaneously developed as the work progresses and as each bench is required.

Quarries are developed by the multiple-bench method when the face is too high for single shots, horizontal seams or separations are present, or deep and narrow deposits exist. This method of development permits equipment to be used simultaneously at more

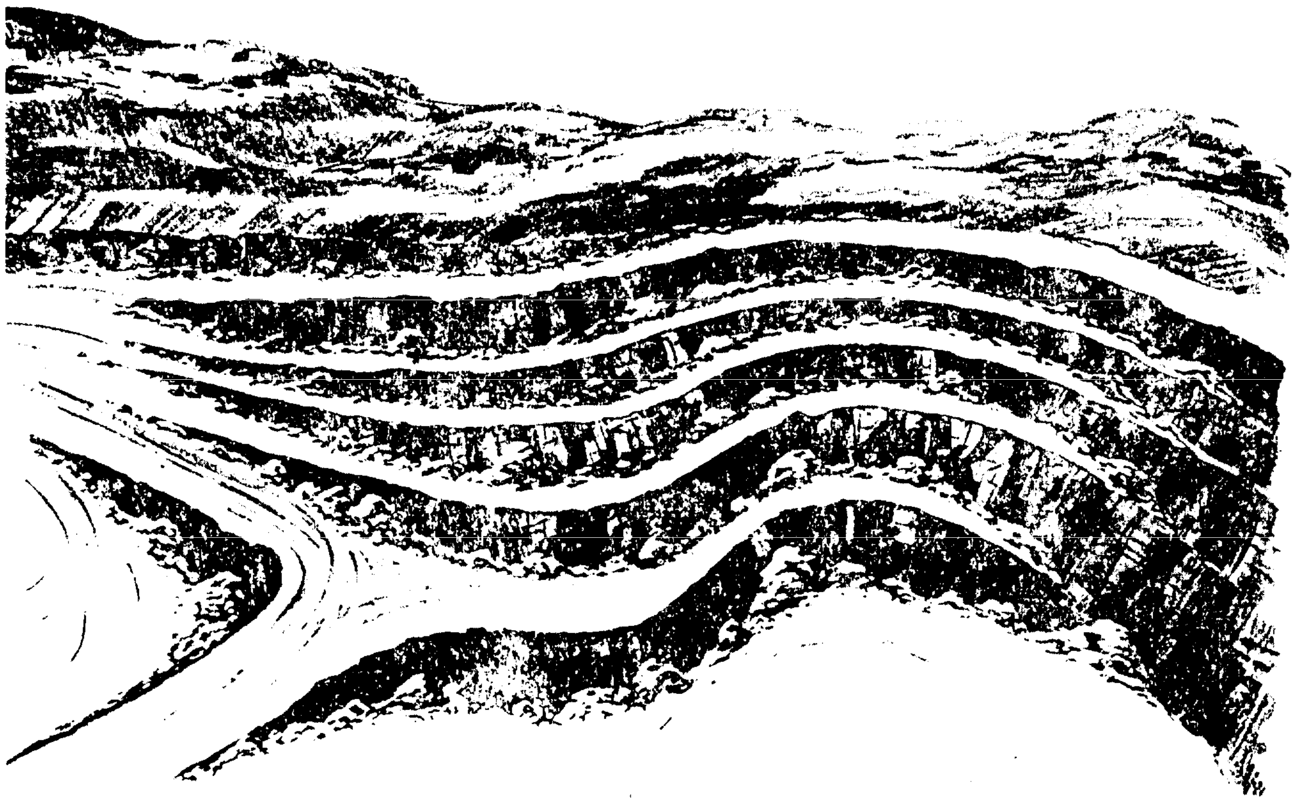

Figure 5-14.-Multiple-bench quarry.

than one level. All benches must be made wide enough to allow the use of equipment to remove blasted rock (50 feet minimum). Multiple-bench quarries make possible greater continuity of operation than single-bench quarries.

NOTE: When you are developing a multibench quarry, blasting must be confined to only one bench at a time. Simultaneous blasting at several levels is NOT permitted under any circumstances.

QUARRY EQUIPMENT

CESE is available in the Naval Construction Force TOA to enable construction units to meet their own aggregate production requirements. Quarry equipment is subject to exceptionally hard wear due to the abrasive action of rock and rock dust; therefore, the operator's maintenance procedures contained in the manufacturer's maintenance and service manuals must be strictly followed.

The equipment used in hard-rock quarries consists of bulldozers, air compressors, rock drills, drill steel and bits, loading and hauling equipment, and miscellaneous tools. As the supervisor in charge of quarry operations, you must ensure that operator's maintenance is performed and that all cutting edges, end bits, teeth and shanks, dozer tracks, tires, blades, and so forth, are checked daily for wear, adjustments, and cracks.

Wearfacing

Equipment used in quarry operations should be wear-faced. Wearfacing greatly extends the usable life of construction equipment, ensures efficient operation with less downtime, and greatly reduces the need for spare parts. Guidelines for wearfacing equipment parts and accessories are outlined in the *NCF Welding Materials Handbook,* NAVFAC P-433.

Wearfacing is commonly known in the NCF as hardfacing. The purpose of hardfacing (fig. 5-15) is to insulate many working parts of equipment from the destructive forces that cause metal wear. The selection of a hardfacing alloy for a certain application is based on the capacity of the alloy to withstand or resist impact and abrasion. Impact refers to a blow or series of blows on a surface that results in a fracture or gradual deterioration. Abrasion is the grinding action that results when one surface slides, rolls, or rubs against another. Under high compressive loads, this action can result in gouging.

Alloys that resist abrasion well are poor in withstanding impact, whereas those that withstand impact well are poor in resisting abrasion; however, there are many alloys whose hardfacing properties fall between two extremes. These alloys offer some protection against abrasion and withstand impact fairly well. The hard-faced welding procedures, the type material the part is manufactured from, and the primary and alternate electrodes to perform the hardfacing procedures are all outlined in NAVFAC P-433. Hardfacing operations must be approved by the maintenance supervisor.

Maintenance

Often, maintenance is put off to a later date because of production. This may satisfy the immediate production demands of the unit, but it is not good for the equipment and creates a lax attitude toward scheduled maintenance. When this occurs, a precedent is set that leads to putting maintenance second to production. Should this happen, it is not long before production rates decline because of equipment breakdowns.

BLASTING OPERATIONS

Blasting operations are usually necessary when working a quarry containing materials that cannot be removed with construction equipment, such as front-end loaders, bulldozers, and hauling equipment. Should this be the case, blasting will come under the direct supervision and control of a qualified blaster who carries the NEC-5708. All other quarry personnel assigned must follow written and oral instructions, carry out assigned duties, and observe all safety precautions.

Limiting the number of personnel handling explosives lessens the risk of accidents occurring. This means one or two blasters have a definite assignment to conduct several of the tasks involved in loading and firing a blast. These tasks include the following: carrying explosives and detonators, opening cases, priming, loading, stemming, connecting blasting circuits, and firing. The entire quarry crew must know exactly what the blaster's duties are. With such a system observed, everything is accomplished in a precise and orderly manner with no haphazard assumption of the various tasks to be performed.

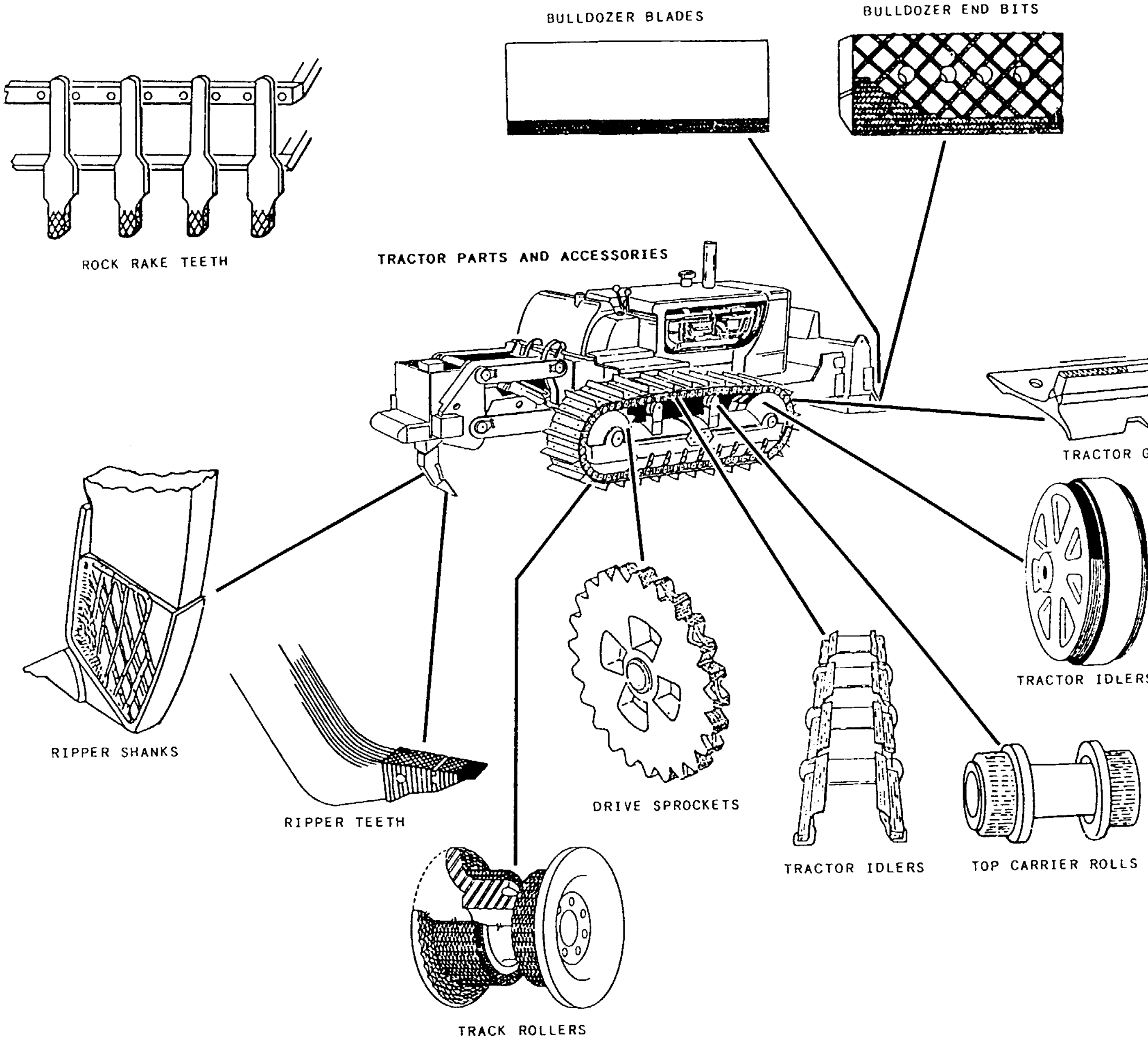

Figure 5-15.–Hard-faced parts and accessories.